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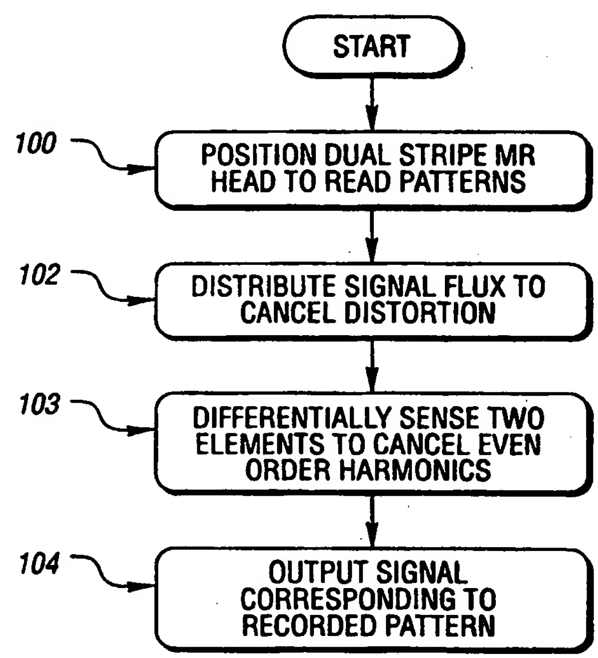
(54) Title: METHOD FOR READING BOTH HIGH AND LOW DENSITY SIGNALS WITH AN MR HEAD

(57) Abstract

A method is provided for reading both high and low density data patterns recorded on a magnetic storage media with a magnetoresistive read head optimized for reading high density patterns. Readback distortion of the low density waveforms is inhibited via distribution (102) of the detected signal flux between two magnetoresistive elements (12, 14) in a dual stripe magnetoresistive read head arrangement. Differential sensing (103) of the two elements cancels second harmonic and higher order even harmonics. Higher signal amplitude is also provided to improve reading of high density patterns.



METHOD FOR READING BOTH HIGH AND LOW DENSITY SIGNALS WITH AN MR HEAD

Technical Field

The present invention generally relates to magnetoresistive (MR) read heads, and more particularly to a method of using a single MR head which can read both low density and high density patterns recorded on a tape or other magnetic media with minimal distortion.

Magnetoresistive (MR) magnetic head assemblies fabricated with thin film technology advantageously provide a means for increasing the bit density in magnetic recording systems. As compared to traditional inductive read heads, these narrow track assemblies provide higher readback amplitude that is independent of the relative velocity between the magnetic media and the head.

Generally, a variety of different signal flux levels can be produced from the various data patterns recorded on a tape. For example, low density patterns present a larger magnetic flux to the MR element leading to higher signal amplitude than high density patterns which have a lower level of magnetic flux. An MR head is typically designed and optimized to read the high density patterns in order to have significant amplitude for signal detection. However, the high input flux from a low density pattern can drive an MR element designed for high density operation into non-linear portions of the MR response curve, leading to readback distortion, even possibly causing the MR element to magnetically saturate.

Write equalization, a method of breaking up the low density signal with high density pulses, is often employed to provide some equalization of the signal flux as detected by the MR element. Unfortunately, due to the increased complexity and cost of implementation, write equalization has not been universally applied in tape recording. Further, the problem of distortion when reading low density waveforms is accentuated in systems where downward read compatibility is required. In such situations the range of recording densities seen by the head can be extreme. Standard read head designs are not capable of producing a sufficient readback amplitude at the high recording density without high readback distortion at the lower densities. Incorporating two read head designs, one optimized for low recording densities and the other optimized for the high density, greatly increases the head and drive complexity and cost.

Disclosure Of The Invention

It is therefore an object of the present invention to provide a method for reading high and low density signals which only requires one MR head.

It is another object of the present invention to provide a method and MR servo reader head capable of reading low density servo patterns of high readback signal amplitude with the same MR head design as used for narrow track data heads which are required to read high density data patterns.

It is yet another object of the present invention to provide a method and MR head optimized to read high density signals stored on a magnetic media

with minimal distortion when reading low density signals.

In accordance with these and other objects, the present invention provides a method for reading both high and low density signal patterns recorded on a magnetic storage media with a magnetoresistive read head comprising positioning the read head relative to the storage media so as to detect a signal flux from any patterns recorded thereon, and distributing the detected signal flux between two separated magnetoresistive elements located in the read head to inhibit low density readback distortion and element saturation. In addition, by differential signal detection of the two elements, the even order distortion of the readback signal is cancelled. This is particularly valuable in minimizing the second harmonic distortion of the readback. A signal is output from the read head corresponding to the recorded pattern.

These and other objects, features and advantages will be readily apparent upon consideration of the following detailed description in conjunction with the accompanying drawings.

Brief Description of the Drawings

Figure 1 is a cross section of a dual stripe magnetoresistive head used in the present invention;

Figure 2 is a characteristic transfer curve for the magnetoresistive element of the present invention illustrating the variation in resistance R versus magnetic field H; and

Figure 3 is a flowchart illustrating the reading operation in accordance with the present invention.

Best Mode For Carrying Out The Invention

Referring to Figure 1, a dual stripe magnetoresistive MR head assembly 10 is shown in accordance with the present invention as being formed with two magnetoresistive elements 12 and 14 separated by a thin insulating layer 16.

The head assembly 10 can be fabricated as a multilayer thin film using conventional vapor deposition, electroplating, and photolithography processes. The MR elements 12 and 14 may be formed as thin ferromagnetic films parallel to one another, and have low anisotropy and a high magnetoresistance coefficient. The MR elements are preferably physically and magnetically matched to each other and have substantially the same thickness, dimensions, resistance, coefficient of the thermal expansion, resistivity and shape anisotropy. The MR elements 12 and 14 have a common junction which is connected to a reference voltage source, such as ground terminal.

A bias current is supplied to both MR elements from an externally located current source. When the bias current is applied to the MR elements, the current through MR element 12 creates a magnetic field that serves to magnetically bias magnetoresistive element 14. Similarly, the current through MR element 14 creates a field that serves to magnetically bias element 12. In addition, the two elements are magnetostatically coupled together which assists in the magnetic biasing of each

element. The thin insulating layer 16 which separates the MR elements electrically isolate one element from the other. Any suitable insulating material may be used, such as silicon nitride, silicon dioxide, or aluminum oxide.

A pair of magnetic shield layers 18 and 20, such as formed from permalloy or NiZn ferrite, prevent the MR elements from sensing distant flux transitions. One prefers that the MR elements only sense a recorded bit when the bit is directly under the MR elements. The spacing between shields 18 and 20 is therefore related to the minimum bit spacing of the recording media. The shield layers 18 and 20 are insulated from the MR elements by insulating layers 22 and 24.

Resistance of an MR element is a function of magnetic field, H, as graphically represented in Figure 2. More specifically, to minimize readback distortion, the MR element must be designed to maintain an operating point within the linear portion of the curve denoted as 26. The operating point of conventional MR head designs which are optimized to read high density signals will move into non-linear regions 28 when reading low density signals.

However, with the present invention, the two MR elements share the signal flux from the tape or magnetic media. The distribution or sharing of the signal flux provides a two-fold advantage, i.e., a higher signal amplitude is generated when reading signals as compared to a single MR element design, and each of the MR elements sees less of the magnetic flux from the tape which increases the likelihood of the element operating in the desired linear response region

26 of the MR transfer curve. The former allows optimization of the head for high density recorded patterns, while the latter allows the same head to also read low density recorded patterns. In addition, by differentially sensing the two elements, second harmonic distortion of the readback signal is largely cancelled. Thus, an MR read head with two MR elements can be presented with a larger range of input flux from the media without significant alteration of the readback signal.

The overall process of the present invention is summarized in the flowchart of Figure 3. As denoted at block 100, the dual stripe MR read head is positioned relative to the magnetic media so as to cause distribution at block 102 of the signal flux produced by any pattern stored thereon between the two MR elements. This distribution decreases distortion by maintaining each MR element in the desired linear response range. At block 103, the signal from the two elements is differentially sensed to cancel second harmonic and higher even order distortion. At block 104, a signal is output from the head corresponding to the pattern stored on the media.

In accordance with one exemplary embodiment of the present invention, MR read heads which read servo patterns and MR read heads which read data patterns can be fabricated from a common thin layer process using the same film thicknesses. More specifically, servo patterns are preferably written at a low density to provide a high readback amplitude and minimum readback loss. With the present invention, a servo reader can be fabricated with data reader heads because the dual stripe arrangement minimizes saturation to allow reading of the low density servo pattern.

It is to be understood, then, that the present invention has been described in a illustrative manner and that the terminology which has been used is intended to be in the nature of words of description rather than of limitation. As previously stated, many modification and variations of the present invention are possible in light of the above teachings. Therefore, it is also to be understood that, within the scope of the following claims, the present invention may be practiced otherwise than as specifically described.

What Is Claimed Is:

1. A method for reading both high and low density signal patterns recorded on a magnetic storage media with a magnetoresistive read head comprising:

positioning said read head relative to said storage media so as to detect a signal flux from any patterns recorded thereon;

distributing the detected signal flux between two separated magnetoresistive elements located in said read head to decrease readback distortion and limit potential element saturation;

differentially sensing the two magnetoresistive elements to cancel even order harmonic distortion; and

outputting a signal from said read head corresponding to the recorded pattern.

2. The method of claim 1 further comprising optimizing said read head for reading high density patterns by arranging the two magnetoresistive elements to increase detected signal amplitude.

3. The method of claim 1 wherein said low density signal pattern comprises a servo pattern recorded onto a tape, and said read head comprises a servo read head having the same design characteristics as a data read head optimized to read high density patterns.

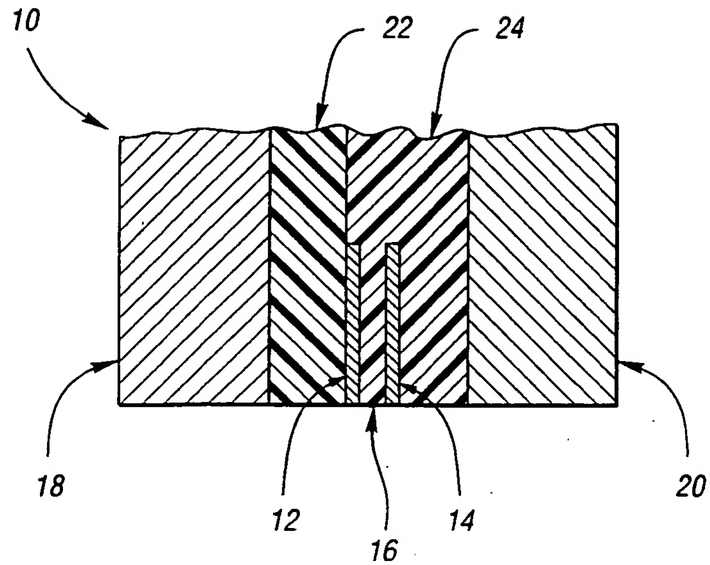


Fig. 1

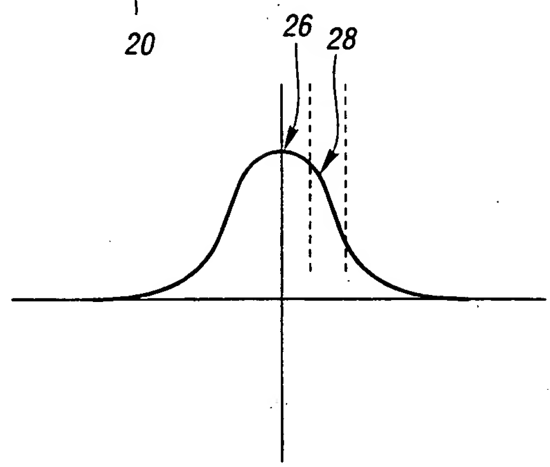


Fig. 2

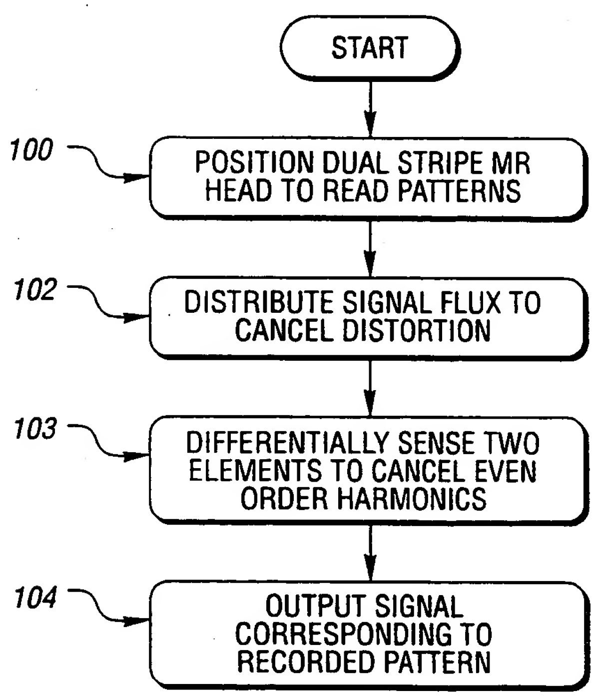


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/10043

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G11B 5/09, 5/02, 5/035, 5/127
US CL : 360/46, 55, 65, 113
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 360/46, 55, 65, 113

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS mr, magnetoresistive, harmonic distortion, differential, high density, low density, servo pattern

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,012,781 A (LIN) 15 March 1977, Figs. 1 and 5, col. 4, lines 24-29, col. 6., line 48 - col. 7, line 26.	1-3
X	US 5,706,151 A (SMITH) 06 January 1998, Figs. 3, 7a, 7b, col. 3, line 66 - col. 4, line 2, col. 5., line 64 - col. 6, line 5.	1-3
X	US 5,309,305 A (NEPELA et al.) 03 May 1994, Figs. 1 and 2, col. 3, line 6 - col. 4, line 18.	1-3
A	US 3,860,965 A (VOEGELI) 14 January 1975.	1-3
A	US 4,589,041 A (VOEGELI) 13 May 1986.	1-3
A	US 5,193,038 A (SMITH) 09 March 1993.	1-3

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

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INTERNATIONAL SEARCH REPORT

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,406,433 A (SMITH) 11 April 1995.	1-3